U.S. Department
of Transportation
**Federal Highway
Administration**

400 Seventh St., S.W.
Washington, D.C. 20590

GUIDELINES FOR PREPARING FEDERAL HIGHWAY ADMINISTRATION PUBLICATIONS (REPORT NO. FHWA-AD-88-001 DATED JANUARY 1988)

CHANGE 1 - MAY 20, 1994

The attached pages transmit the Metric System revisions to this publication.

These changes are required to bring the metric system usage in all FHWA publications into conformance with the Federal policy mandating its use. Revisions to paragraph 10c(4), Metric Conversion Factors Page, specify inclusion of metric conversion factors. New paragraph 20 details the requirements and staging of standard practice in the use of metric units in technical FHWA publications. Attachments 8 and 9 provide guidance for current style, usage, accuracy, and rounding of metric measurements.

Glenn K. Vinson
Chief, Publishing and
Visual Communications Branch

PAGE CHANGE INSTRUCTIONS

REMOVE	INSERT
pages 5-19 and 5-20 dated 12/23/87	5-19, 5-20, and 5-41 thru 5-43
	Attachment 8
	Attachment 9

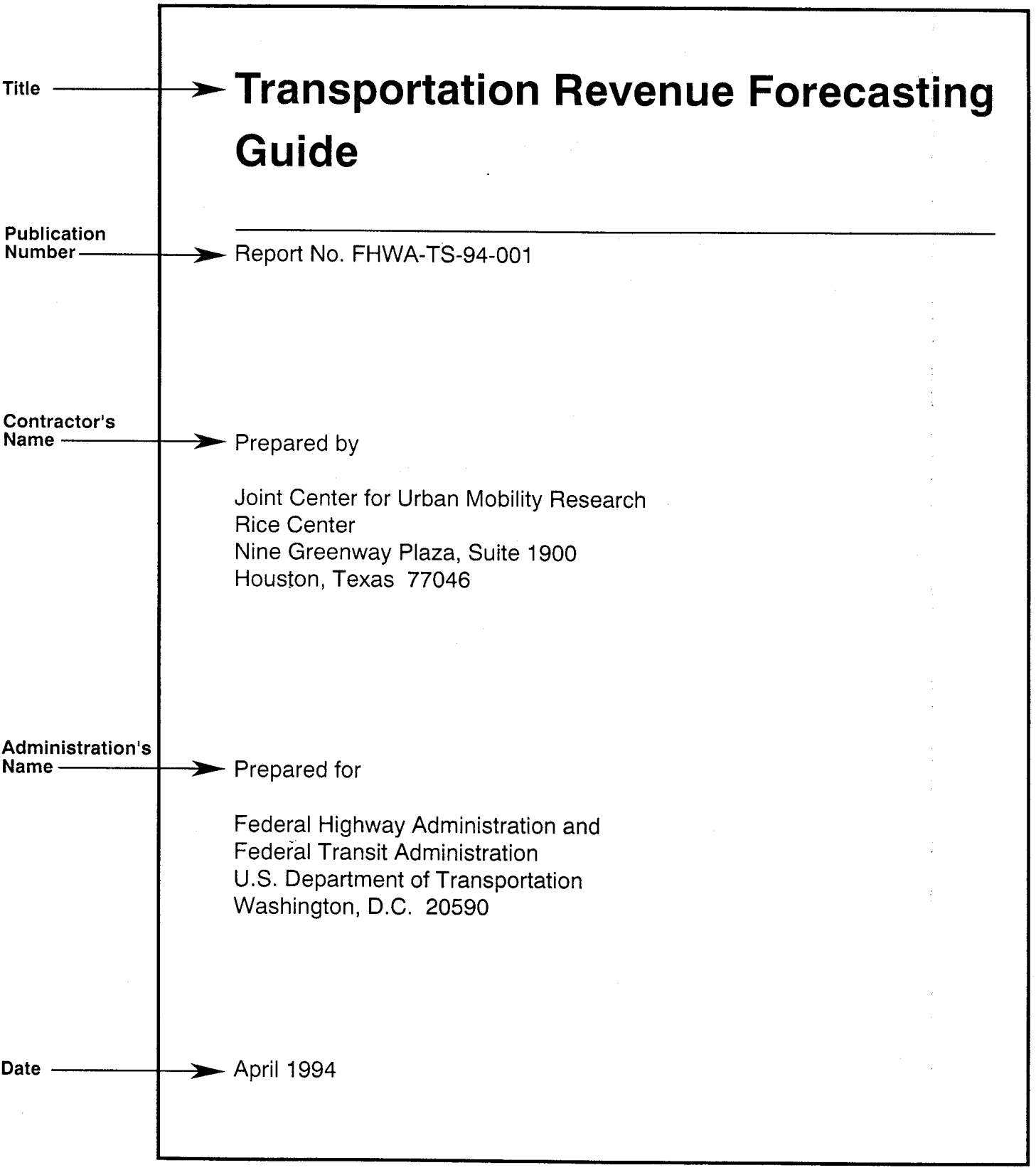

Figure 5.11. Sample Title Page with Byline

received (see Credit Lines, paragraph 7a). If acknowledgments are too long, they may be put on the page following the preface. See Figures 5.12 and 5.13 for examples of a preface and separate acknowledgment page.

(4) Metric Conversion Factors Page. Include a Metric Conversion Factors page (Figure 5.14) if measurements are used in the publication. This page provides the reader with information for converting metric measurements to inch-pound measurements if necessary. Additional units may be included as they apply to the contents of the report. Figure 5.14 may be reproduced. Copies also can be obtained from the Management Services Division (HMS-22). The Metric Conversion Factors page should be placed as part of the front matter text, before the main part of the text begins. Specific FHWA uses of the International System of Units (SI) in publications are outlined in Chapter 5, paragraph 20.

(5) Table of Contents. A table of contents (Figure 5.15) is useful in most publications of more than 10 pages and required in all publications of 30 or more pages. In preparing the table of contents, these rules should be followed:

(a) Front matter preceding the table of contents should not be listed. Begin with the introduction or first section, which follows the table of contents.

(b) List every section or subsection title. All capitals or initial capital letters may be used for the titles, but each level of headings must be consistent (e.g., main headings in all capitals, subheadings in initial capitals, etc.). If both headings and subheadings are used, bold typeface is recommended for the main headings. The relationship between the levels of headings and subheadings also can be emphasized by indenting the subheadings.

(c) Use titles identical to the headings in the publication.

(d) Use numbers or letters identical to those found in the publication.

20. METRIC UNITS OF MEASUREMENT

a. Public Law 100-418 requires Federal agencies to use the metric system in grants, procurements, and in the conduct of other business activities to the extent economically feasible. DOT Order 1020.1D, *Department of Transportation Transition to the Metric System*, dated March 23, 1992, and the phased "FHWA Metric Conversion Plan (MCP)," dated June 1991, establish guidance and timing for the Administration. FHWA is in compliance with this guidance, and intends that the policies and deadline timing of this plan be followed in all FHWA publications.

b. The plan contains the Administration's schedule for undertaking metric conversion activities and actions. The FHWA is committed to avoid dualization in reports and correspondence beyond October 1, 1993, to the maximum extent practical, unless it is determined in specific instances that continuing to publish dual units of measurement would be beneficial.

c. Consistent with this plan and to bring all FHWA technical reports and publications into compliance, metric units only shall be used in all new or revised technical publications, standards, and specifications.

(1) Schedule. FHWA offices shall refer to the Metric Work Plan bar graph summaries in the MCP to comply with their offices' deadlines for completing "soft" and "hard" conversion phases.

(2) Metrication

(a) Metric units of measurement (abbreviated SI from the French *Le Système International d'Unités*) and the common (sometimes called the imperial, U.S., or English) inch-pound system of measurement can be converted mathematically back and forth, which is sometimes called a "soft" conversion.

(b) Soft conversion is a direct conversion to SI, wherein an inch-pound measurement is mathematically converted to its exact (or near exact) metric equivalent and then rounded to the minimum number of significant digits that will maintain the required accuracy. For example, a 4′ x 8′ sheet of plywood becomes 1219 mm x 2438 mm rounded to the accuracy of the mm.

(c) With "hard" conversion, a new rationalized metric number is chosen that is convenient to work with and remember. The same 4′ x 8′ sheet becomes a new standard having the dimensions of 1200 mm x 2400 mm. Refer to appendix C of the MCP for further highway-specific examples of "hard" and "soft" metric conversions.

(3) Usage. *Standard Practice for Use of the International System of Units (SI)*, E 380-92, provides guidelines for international usage and shall prevail in FHWA publications. *Preferred Metric Units for General Use by the Federal Government*, Federal Standard 376B, January 27, 1993, published by the General Services Administration, lists metric units recommended for use by the Interagency Council. Style and usage sections from *Standard Practice* are reprinted as Attachment 8, and accuracy and rounding are reprinted as Attachment 9. *Standard Practice* is a publication of the American Society for Testing and Materials (see below).

(4) FHWA-Specific Applications

(a) Convert historic records and data to metric measurements only when necessary for ongoing operations and future projections (Federal Register, Vol. 57, No. 113, May 11, 1992 Notices, page 24845).

(b) Meter and liter are FHWA preferred spellings, notwithstanding unit usage noted in SI *Standard Practice*.

(c) If dual use of measurements must continue in specific instances where such usage will be beneficial, show SI first, followed by inch-pound equivalents enclosed in parentheses.

(d) Allow inch-pound measurements to stand in existing publications if changes would require retyping, reformatting, or reprinting.

(5) Useful Writer's References and Sources:

(a) "FHWA Metric Conversion Plan," June 1991, available from HNG-22/FHWA Metric Coordinator

(b) *Standard Practice for Use of the International System of Units (SI)* E 380-92, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103

(c) *Metric Guide for Federal Construction*, published by the National Institute of Building Sciences, 1201 L St. NW, Washington, DC 20005

(d) *Interim Selected Metric Values for Geometric Design*, published by the American Association of State Highway and Transportation Officials, 444 N. Capitol St. NW - Suite 249, Washington, DC 20001

(e) *Guide to Metric Conversion*, published by the American Association of State Highway and Transportation Officials, 444 N. Capitol St. NW - Suite 249, Washington, DC 20001

(f) *Preferred Metric Units for General Use by the Federal Government*, Federal Standard 376B, published by GSA, dated January 27, 1993

4.5 *Style and Usage*—Care must be taken to use unit symbols properly, and international agreement provides uniform rules. Handling of unit names varies because of language differences, but use of the rules included here will improve communications in the United States.

4.5.1 *Rules for Writing Unit Symbols:*

4.5.1.1 Unit symbols should be printed in upright type regardless of the type style used in the surrounding text.

4.5.1.2 Unit symbols are unaltered in the plural.

4.5.1.3 Unit symbols are not followed by a period except when used at the end of a sentence.

4.5.1.4 Letter unit symbols are written in lower-case (for example, cd) unless the unit name has been derived from a proper name, in which case the first letter of the symbol is capitalized (for example, W, Pa). The exception is the symbol for litre, L. Prefix symbols use either lower-case or upper-case letters as shown in 3.5.1. Symbols retain their prescribed form regardless of the surrounding typography. For symbols for use in systems with limited character sets, refer to ANSI X3.50 or ANSI/IEEE 260, as applicable. The symbols in ANSI X3.50 are intended for applications in the field of information processing, where unambiguous transmission of information between computers is required. The symbols in ANSI/IEEE 260 are generally consistent with those in ANSI X3.50 and are intended for communication between human beings. The symbols for limited character sets must never be used when the available character set permits the use of the proper general-use symbols as given in this standard.

4.5.1.5 When a quantity is expressed as a numerical value and a unit symbol, a space should be left between them. For example, use 35 mm, *not* 35mm, and 2.37 lm (for 2.37 lumens), *not* 2.37lm.

Exception: No space is left between the numerical value and the symbols for degree, minute, and second of plane angle, and degree Celsius. For example, use 45°, 20°C.

4.5.1.6 When a quantity expressed as a number and a unit is used in an adjectival sense, it is preferable to use a hyphen instead of a space between the number and the unit name or between the number and the symbol. Examples: A three-metre pole... The length is 3 m... A 35-mm film... The width is 35 mm. However, per 4.5.1.5 Exception, a 90° angle ... an angle of 90°.

4.5.1.7 No space is used between the prefix and unit symbols.

4.5.1.8 Symbols, not abbreviations, should be used for units. For example, use "A" and not "amp" for ampere.

4.5.2 *Rules for Writing Names:*

4.5.2.1 Spelled-out unit names are treated as common nouns in English. Thus, the first letter of a unit name is not capitalized except at the beginning of a sentence or in capitalized material such as a title.

4.5.2.2 Plurals are used when required by the rules of English grammar and are normally formed regularly, for example, henries for the plural of henry. The following irregular plurals are recommended:

Singular	Plural
lux	lux
hertz	hertz
siemens	siemens

4.5.2.3 No space or hyphen is used between the prefix and unit name. There are three cases where the final vowel in the prefix is commonly omitted: *megohm, kilohm,* and *hectare.* In all other cases where the unit name begins with a vowel both vowels are retained and both are pronounced.

4.5.3 *Units Formed by Multiplication and Division:*

4.5.3.1 With unit names:

Product, use a space (preferred) or hyphen:

newton metre *or* newton-metre

In the case of the watt hour the space may be omitted, thus:

watthour

Quotient, use the word *per* and not a solidus:

metre per second, *not* metre/second

Powers, use the modifier *squared* or *cubed* placed after the unit name:

metre per second squared

In the case of area or volume, the modifier may be placed before the unit name:

square millimetre, cubic metre

This alternative is also allowed for derived units that include area or volume:

watt per square metre

NOTE—To avoid ambiguity in complicated expressions, symbols are preferred over words.

4.5.3.2 With unit symbols:

Product, use a raised dot:

N·m for newton metre

In the case of W·h, the dot may be omitted, thus:

Wh

An exception to this practice is made for computer printouts, automatic typewriter work, etc., where the raised dot is not possible, and a dot on the line may be used.

Quotient, use one of the following forms:

m/s *or* $m \cdot s^{-1}$ *or* $\frac{m}{s}$

In no case should more than one solidus be used in the same expression unless parentheses are inserted to avoid ambi-

guity. For example, write:

$$J/(mol \cdot K) \text{ or } J \cdot mol^{-1} \cdot K^{-1} \text{ or } (J/mol)/K,$$

but *not*

$$J/mol/K$$

4.5.3.3 Symbols and unit names should not be mixed in the same expression. Write:

$$\text{joules per kilogram or } J/kg \text{ or } J \cdot kg^{-1}$$

but *not*

$$\text{joules/kilogram nor joules/kg nor joules} \cdot kg^{-1}$$

4.5.4 *Numbers:*

4.5.4.1 The recommended decimal marker is a dot on the line. When writing numbers less than one, a zero should be written before the decimal marker.

4.5.4.2 Outside the United States, the comma is often used as a decimal marker. In some applications, therefore, the common practice in the United States of using the comma to separate digits into groups of three (as in 23,478) may cause ambiguity. To avoid this potential source of confusion, recommended international practice calls for separating the digits into groups of three, counting from the decimal point toward the left and the right, and using a small space to separate the groups. In numbers of four digits on either side of the decimal point the space is usually not necessary, except for uniformity in tables.

Examples:

2.141 596 73 722 7372 0.1335

Where this practice is followed, the space should be narrow (approximately the width of the letter "i"), and the width of the space should be constant even if, as is often the case in printing, variable-width spacing is used between words. Exceptions: In certain specialized applications, such as engineering drawings and financial statements, the practice of using a space for a separator is not customary.

4.5.4.3 Because *billion* means a thousand million (prefix *giga*) in the United States but a million million (prefix *tera*) in most other countries, this term and others, such as trillion, should be avoided in technical writing.

4.5.4.4 Use of M to indicate thousands, as in MCF for thousands of cubic feet, or in MCM for thousands of circular mils, of MM to indicate millions, of C to indicate hundreds, etc., is deprecated because of obvious conflicts with the SI prefixes.

4.5.5 *Attachment*—Attachment of letters to a unit symbol as a means of giving information about the nature of the quantity under consideration is incorrect. Thus MWe for "megawatts electrical (power)," Vac for "volts ac," and kJt for "kilojoules thermal (energy)" are not acceptable. For this reason, no attempt should be made to construct SI equivalents of the abbreviations "psia" and "psig," so often used to distinguish between absolute and gage pressure. If the context leaves any doubt as to which is meant, the word *pressure* must be qualified appropriately. For example:

"... at a gage pressure of 13 kPa"

or

"... at an absolute pressure of 13 kPa"

Where space is limited, such as on gages, nameplates, graph labels, and in table headings, it is permissible to use the unit symbol followed by a space and the modifier in parentheses. For example: V (ac) and V (dc); kPa (gage) and kPa (absolute).

4.5.6 *Pronunciation*—Some recommended pronunciations in English are shown in Table 8.

TABLE 8 Recommended Pronunciation

Prefix	Pronunciation (USA)[A]
exa	ex' a (*a* as in *a*bout)
peta	pet' a (*e* as in pet, *a* as in *a*bout)
tera	as in *terra* firma
giga	jig' a (*i* as in *j*ig, *a* as in *a*bout)
mega	as in *mega*phone
kilo	kill' oh
hecto	heck' toe
deka	deck' a (*a* as in *a*bout)
deci	as in *deci*mal
centi	as in *centi*pede
milli	as in *mili*tary
micro	as in *micro*phone
nano	nan' oh (*an* as in *an*t)
pico	peek' oh
femto	fem' toe (*fem* as in *fem*inine)
atto	as in an*a*tomy

Selected Units	Pronunciation
candela	can *dell'* a
joule	rhyme with *tool*
kilometre	*kill'* oh metre
pascal	rhyme with *rascal*
siemens	same as *seamen's*

[A] The first syllable of every prefix is accented to assure that the prefix will retain its identity. Therefore, the preferred pronunciation of kilometre places the accent on the first syllable, *not* the second.

Style and Usage, Section 4.5 of ASTM E 380-93, **Standard Practice for Use of the International System of Units**

5.2 *Accuracy and Rounding*—A conversion obtained by multiplying a value by a seven-digit factor usually gives a product with more digits than the original value. The converted value must be rounded to the proper number of significant digits commensurate with the intended accuracy. Conversions usually yield a product with more digits than the original value. The practical aspect of measuring must be considered when using SI equivalents. If a scale having division of 1/16 inch was suitable for making the original measurements, a metric scale having divisions of 1 mm is obviously suitable for measuring in SI units. Similarly, a gage or caliper graduated in divisions of 0.02 mm is comparable to one graduated in divisions of 0.001 in. Analogous situations exist in mass, force, and other measurements. Many techniques are used to guide the determination of the proper number of significant digits in the converted values. Two different approaches to rounding of quantities are here described—one for general use and the other for conversion of dimensions involving mechanical interchangeability.

5.2.1 *General Conversion*—This approach depends on first establishing the intended precision or accuracy of the quantity as a necessary guide to the number of digits to retain. This precision should relate to the number of digits in the original, but in many cases this is not a reliable indicator. A figure 1.1875 may be a very accurate decimalization of a noncritical 13/16 that should have been expressed 1.19. On the other hand, the value 2 may mean "about 2," or it may mean a very accurate value of 2 which should have been written 2.0000. It is therefore necessary to determine the intended precision of a quantity before converting. This estimate of intended precision should never be smaller than the accuracy of measurement and should usually be smaller than one tenth the tolerance if one exists. After estimating the precision of the dimension, the converted dimension should be rounded to a minimum number of significant digits (see 5.3) such that a unit of the last place is equal to or smaller than the converted precision. Examples:

1. A stirring rod 6 in long. In this case, precision is estimated to be about 1/2 in (± 1/4 in). Converted, this is 12.7 mm. The converted dimension 152.4 mm should be rounded to the nearest 10 mm, or 150 mm.

2. 50 000 lbf/in^2 (psi) tensile strength. In this case, precision is estimated to be about ± 200 lbf/in^2 (± 1.4 MPa) based on an accuracy of ± 0.25 % for the tensile tester and other factors. Therefore, the converted dimension, 344.7379 MPa, should be rounded to the nearest whole unit, 345 MPa.

3. Test pressure 200 ± 15 lbf/in^2 (psi). Since one tenth of the tolerance is 3 lbf/in^2 (20.68 kPa), the converted dimension should be rounded to the nearest 10 kPa. Thus, 1378.9514 ± 103.421 35 kPa becomes 1380 ± 100 kPa.

5.2.2 *Special Cases:*

5.2.2.1 Converted values should be rounded to the minimum number of significant digits that will maintain the required accuracy, as discussed in 5.1.2. In certain cases deviation from this practice to make use of convenient or whole numbers may be feasible, in which case the word "approximate" must be used following the conversion. For example:

1 7/8 in = 47.625 mm exact
47.6 mm normal rounding
47.5 mm (approx) rounded to preferred number
48 mm (approx) rounded to whole number

5.2.2.2 A quantity stated as a limit, such as "not more than" or "maximum," must be handled so that the stated limit is not violated. For example, a specimen "at least 4 in wide" requires a width of at least 101.6 mm, or at least 102 mm.

5.3 *Significant Digits:*

5.3.1 When converting integral values of units, consideration must be given to the implied or required precision of the integral value to be converted. For example, the value "4 in" may be intended to represent 4, 4.0, 4.00, 4.000, or 4.0000 in, or even greater accuracy. Obviously, the converted value must be carried to a sufficient number of digits to maintain the accuracy implied or required in the original quantity.

5.3.2 Any digit that is necessary to define the specific value or quantity is said to be significant. When measured to the nearest 1 m, a distance may be recorded as 157 m; this number has three significant digits. If the measurement had been made to the nearest 0.1 m, the distance may have been 157.4 m; this number has four significant digits.

5.3.3 Zeros may be used either to indicate a specific value, like any other digit, or to indicate the order of magnitude of a number. The 1970 United States population figure rounded to thousands was 203 185 000. The six left-hand digits of this number are significant; each *measures* a value. The three right-hand digits are zeros which merely indicate the order of *magnitude* of the number rounded to the nearest thousand. The identification of significant digits is only possible through knowledge of the circumstances. For example, the number 1000 may be rounded from 965, in which case only one zero is significant, or it may be rounded from 999.7, in which case all three zeros are significant.

5.3.4 Occasionally data required for an investigation must be drawn from a variety of sources where they have been recorded with varying degrees of refinement. Specific rules must be observed when such data are to be *added, subtracted, multiplied,* or *divided.*

5.3.4.1 The rule for addition and subtraction is that the *answer* shall contain no significant digits farther to the right than occurs in the least precise number. Consider the addition of three numbers drawn from three sources, the first of which reported data in millions, the second in thousands, and the third in units:

163 000 000
217 885 000
96 432 768
477 317 768

The total indicates a precision that is not valid. The numbers should first be rounded to *one significant digit* farther to the right than that of the least precise number, and the sum taken as follows:

163 000 000
217 900 000
96 400 000
477 300 000

The total is then rounded to 477 000 000 as called for by the rule. Note that if the second of the figures to be added had been 217 985 000, the rounding before addition would have produced 218 000 000, in which case the 0 following 218 would have been a significant digit.

5.3.4.2 The rule for multiplication and division is that the *product* or *quotient* shall contain no more significant digits than are contained in the number with the *fewest significant digits* used in the multiplication or division. The difference between this rule and the rule for addition and subtraction should be noted; the latter rule merely requires rounding of digits that lie to the right of the last significant digit in the least precise number. The following illustration highlights this difference:

Multiplication:
113.2 × 1.43 = 161.876, rounded to 162
Division:
113.2 ÷ 1.43 = 79.16, rounded to 79.2
Addition:
113.2 + 1.43 = 114.63, rounded to 114.6
Subtraction:
113.2 − 1.43 = 111.77, rounded to 111.8

The above product and quotient are limited to three significant digits since 1.43 contains only three significant digits. In contrast, the rounded answers in the addition and subtraction examples contain four significant digits.

5.3.4.3 Numbers used in the above illustrations have all been estimates or measurements. Numbers that are exact counts are treated as though they consist of an infinite number of significant digits. More simply stated, when a count is used in computation with a measurement the number of significant digits in the answer is the same as the number of significant digits in the measurement. If a count of 40 is multiplied by a measurement of 10.2, the product is 408. However, if 40 were an estimate accurate only to the nearest 10, and hence contained but one significant digit, the product would be 400.

5.4 *Rounding Values*[7]:

5.4.1 When a figure is to be rounded to fewer digits than the total number available, the procedure should be as follows:

5.4.1.1 When the first digit discarded is less than 5, the last digit retained should not be changed. For example, 3.463 25, if rounded to four digits, would be 3.463; if rounded to three digits, 3.46.

5.4.1.2 When the first digit discarded is greater than 5, or if it is a 5 followed by at least one digit other than 0, the last digit retained should be increased by one unit. For example 8.376 52, if rounded to four digits, would be 8.377; if rounded to three digits 8.38.

5.4.1.3 When the first digit discarded is exactly 5, followed only by zeros, the last digit retained should be rounded upward if it is an odd number, but no adjustment made if it is an even number. For example, 4.365, when rounded to three digits, becomes 4.36. The number 4.355 would also round to the same value, 4.36, if rounded to three digits.

Accuracy and Rounding, Section 5.2 - 5.4 of ASTM E 380-93, **Standard Practice for Use of the International System of Units**

*U.S. G.P.O.:1994-301-717:10